

data of spin valve devices in test patterns.

Table 11

Spin Valve Film Constitution:

5 nanometer Ta/free layer/3 nm Cu/ferromagnetic layer A/0.9 nm Ru/ferromagnetic layer B/10 nm IrMn/5 nanometer Ta

Device Constitution: lead-overlaid structure (with no shield)

Subbing hard film/longitudinal bias of CoPt/FeCo is formed on the non-patterned lower shield and lower cap, and the electrode spacing is narrower than the longitudinal bias spacing.

Electrode spacing = 1.3  $\mu\text{m}$

Magnetic Thickness Ratio ( $\text{Ms}\cdot\text{t}$ )A/ ( $\text{Ms}\cdot\text{t}$ )B	Ferro-magnetic Layer A	Ferro-magnetic Layer B	Free Layer	Spinning Magnetization Reversal Voltage	Breakdown Voltage
0.75	2nmCoFe	1.5nmCoFe	3nmCoFe/ 1.5nmNiFe	not reversed	70V
0.8	2.5nmCoFe	2nmCoFe	3nmCoFe/ 1.5nmNiFe	not reversed	75V
0.83	3nmCoFe	2.5nmCoFe	4nmCoFe/ 1.8nmNiFe	not reversed	70V
0.85	2nmCoFe	1.7nmCo	0.5nmCoFe/ 4nmNiFe	not reversed	70V
0.71	2.4nmCoFe	1.7nmCoFe	1nmCoFe/ 3nmNiFe	65V	75V
0.88	2.4nmCoFe	2.1nmCoFe	1nmCoFe/ 3nmNiFe	65V	75V
1	3nmCoFe	3nmCoFe	4nmCoFe/ 1.8nmNiFe	50V	75V
0.667	3nmCoFe	2nmCoFe	3nmCoFe/ 1.5nmNiFe	55V	75V
0.93	3nmCoFe	2.8nmCoFe	1nmCoFe/ 3nmNiFe	55V	70V

In ESD, a magnetic field essentially of the current magnetic field is applied to the pinned magnetic layer in such manner that the magnetic field intensity to the ferromagnetic layer B is larger than that to the ferromagnetic layer A, while, on the other hand, the current magnetic field ratio,  $H(\text{current})_B/H(\text{current})_A$  is nearly equal to the inverse ratio of magnetic thicknesses,  $(Ms \cdot t)_A/(Ms \cdot t)_B$ . In that condition, therefore, the magnetic energy changes due to the ESD current field of the ferromagnetic layers A and B cancel, thereby resulting in that the total energy change of:

$$\{(Ms \cdot t) \cdot H(\text{current})\}_A - \{(Ms \cdot t) \cdot H(\text{current})\}_B$$

is reduced. As a result, the magnetization of the pinned magnetic layer could not be moved in the ESD current magnetic field.

As in Fig. 23C, when the ferromagnetic layer A is 3 nanometers thick and the ferromagnetic layer B is 2 nanometers thick and therefore  $(Ms \cdot t)_B/(Ms \cdot t)_A = 0.67$ , then  $H_{UA}^*$  is lower than that in the case of Fig. 23A where both the ferromagnetic layers A and B are 3 nanometers thick, and therefore, the thermal stability of the pinned magnetic layer in the case of Fig. 23C is lower than that in the case of Fig. 23A. In that case where the magnetic thickness of the ferromagnetic layer B is smaller than that of the ferromagnetic layer A, it is desirable that the current flow direction of the sense current